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(54) Title: WATERMELON MILL

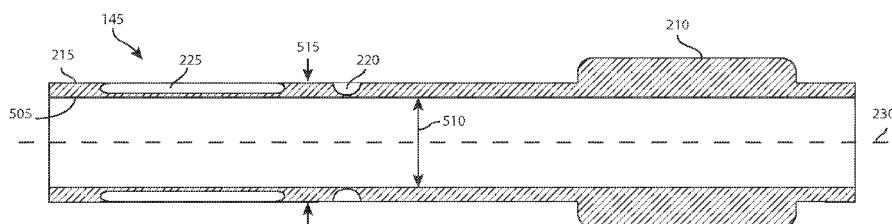


Fig. 5

(57) Abstract: A telemetry device is mounted on a sensor/telemetry part. A sensor is mounted on the sensor/telemetry part. A mill part is coupled to the sensor/telemetry part. A longitudinal axis passes through the sensor/telemetry part and the mill part. A bore passes through the sensor/telemetry part and the mill part along the longitudinal axis.

Watermelon Mill

Background

[0001] In the oilfield, a borehole is often drilled with a drill string made up of tubular (e.g., drill pipe) with a bottom hole assembly (BHA), including a drill bit, at the end of the drill string. Drilling mud is conventionally circulated down a bore through the drill string, out through the drill bit, and up an annulus between the tubular and the borehole wall. The drilling mud performs a number of functions, including cooling the drill bit and carrying cuttings to the surface. In some drilling systems, measurement while drilling (MWD) tools or logging while drilling (LWD) tools are mounted in or close to the BHA to monitor the weight on bit, torque on bit, and bending moment applied to the bit. The DRILLDOC® tool, provided by the assignee of the instant application under a license agreement with APS Technology, provides to equipment on the surface real-time measurements of weight, bending moment, and vibration on bit to characterize the transfer of energy from the surface to the bit.

[0002] Drillers sometimes drill multilateral wells with multiple boreholes branching off a main borehole. In some cases, special tools are used to create the branching boreholes. Often, a lead mill and a watermelon mill are used to cut a window in a borehole wall to start a lateral well borehole. It is a challenge to monitor the weight, torque, bending moment, and vibration on the milling tools while maintaining an adequate flow of drilling mud during the milling operation.

Brief Description of the Drawings

[0003] Fig. 1 is an elevation view of an example system for drilling operations.

[0004] Fig. 2 is a plan view of a watermelon mill with sensors and telemetry devices in which the watermelon mill is separate from the sensors and telemetry devices.

[0005] Fig. 3 is a plan view of a watermelon mill with sensors and telemetry devices in which the watermelon mill is integral with the sensors and telemetry devices.

[0006] Fig. 4 is a cross-sectional view of the watermelon mill with sensors and telemetry devices of Fig. 2.

[0007] Fig. 5 is a cross-sectional view of the watermelon mill with sensors and telemetry devices of Fig. 3.

[0008] Fig. 6 is a flow chart of a process for performing a milling operation using the watermelon mills with sensors and telemetry devices of Figs. 2 and 3.

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Detailed Description

[0009] The following detailed description illustrates embodiments of the present disclosure. These embodiments are described in sufficient detail to enable a person of ordinary skill in the art to practice these embodiments without undue experimentation. It should be understood, however, that the embodiments and examples described herein are given by way of illustration only, and not
10 by way of limitation. Various substitutions, modifications, additions, and rearrangements may be made that remain potential applications of the disclosed techniques. Therefore, the description that follows is not to be taken as limiting on the scope of the appended claims. In particular, an element associated with a particular embodiment should not be limited to association with that particular embodiment but should be assumed to be capable of association with any embodiment discussed
15 herein.

[0010] Further, while this disclosure describes a land-based drilling system, it will be understood that the equipment and techniques described herein are applicable in sea-based systems, multilateral wells, all types of drilling systems, all types of rigs, measurement while drilling (“MWD”)/logging while drilling (“LWD”) environments, wired drillpipe environments, coiled
20 tubing (wired and unwired) environments, wireline environments, and similar environments.

[0011] Fig. 1 is an elevation view of an example system for drilling operations (or “drilling system”) 105 that includes a drilling rig 110 at a surface 115, supporting a drill string 120. The drill string 120 is an assembly of tubular sections (e.g., drill pipe or wired drillpipe), which are connected end-to-end through a work platform 125 into a borehole 130 that penetrates formations
25 135 and 140. Alternatively, the drill string 120 comprises coiled tubing rather than individual tubular sections.

[0012] When it is desired to drill a branching borehole, the drill string 120 is withdrawn from the borehole 130 and a milling tool 145, such as a watermelon mill, and a lead milling tool 150, such

as a lead mill or a drilling bit (e.g., a polycrystalline diamond compact (PDC) bit), are coupled to the drill string 120. A whipstock assembly 155 is then positioned in the borehole 130 at the location where the branching borehole is to be drilled. The milling assembly comprising the milling tool 145 and the lead milling tool 150, is then lowered into the borehole 130 until it engages
5 the whipstock assembly 155. The whipstock assembly 155 orients the lead milling tool 150 and the milling tool 145 to mill a window 160 through the wall of the borehole (which may include casing and/or cement). The lead mill 150 then drills a rat hole 165. The milling tool 145 widens the window 160 and the rat hole 165. A surface equipment 170 communicates with the milling tool 145 to retrieve data collected by the milling tool 145. Such data is used to control, for example,
10 the weight, torque, and bending moment being applied to the milling tool 145 and the lead milling tool 150 to prevent undue wear or failure of such equipment.

[0013] Fig. 2 is a plan view of a watermelon mill with sensors and telemetry devices in which the watermelon mill is separate from the sensors and telemetry devices. The milling tool 145 is divided into two parts: a mill part 210 and a sensor/telemetry part 215. The mill part 210 includes
15 a conventional milling tool, such as a watermelon mill, a junk mill, a pilot mill, or a rotary shoe. The sensor/telemetry part 215 includes sensors 220, such as weight on bit sensors, torque sensors, bending sensors, vibration sensors, pressure sensors (annulus and bore), flow sensors, and revolutions per minute (RPM) sensors. The sensor/telemetry part 215 includes a controller (not shown) to control the sensors 220. The sensor/telemetry part 215 may include memory devices
20 (not shown) to record sensor data that can be retrieved at the surface after a milling operation is completed. The controller processes data from the sensors 220 and sends it to the surface 115 via the telemetry device 225.

[0014] The sensor/telemetry part 215 may include a telemetry device 225. The telemetry device 225 is part of a pulsing bidirectional telemetry system that communicates information, such as
25 data, with the surface equipment 170 by way of a signal comprising controlled pressure deviations, e.g. pulses, transmitted through the drilling mud. Telemetry may be transmitted between the milling tool 145 and the surface equipment 170 using other telemetry techniques. The telemetry device may be part of a conventional MWD tool (not shown) and there may be hardwired drill pipe (not shown) between the conventional MWD tool and the milling tool 145 to carry data
30 between the milling tool 145 and the surface equipment 170. Communications between the MWD

tool and the milling tool may include bidirectional short hop communications, using mud pulse, acoustic, or electromagnetic telemetry. The milling tool 145 may include a battery (not shown) to power the sensors 220 and the telemetry device. The sensors 220 and the telemetry device 225 may receive power from another downhole source (not shown), such as a downhole generator. In operation, the telemetry device 225 may transmit data to the surface equipment 170 or receive data or commands from the surface equipment 170. The surface equipment 170 may use the data to control the drilling of the window 160 and the rat hole 165.

[0015] The milling tool 145 has a longitudinal axis 230, which is an axis that extends generally (i.e., within 10 degrees) in the direction that the milling tool 145 progresses during a milling operation. Further, the milling tool 145 rotates generally (i.e., within 10 degrees) about the longitudinal axis 230 when the milling operation involves rotating the drill string 120.

[0016] A stabilizer 235 may be included that provides a housing for the sensors 220, the telemetry devices 225, the memory devices, and the controller. Further, the stabilizer helps center the milling tool 145 during a milling operation. The mill part 210 includes a mill 240.

[0017] Fig. 3 is a plan view of a watermelon mill with sensors and telemetry devices in which the watermelon mill is integral with the sensors and telemetry devices, i.e., the sensor/telemetry part 215 is integral with the mill part 210. In milling operations, the housing 145 rotates generally (i.e., within 10 degrees) about the longitudinal axis 230.

[0018] Fig. 4 is a cross-sectional view of the watermelon mill with sensors and telemetry devices of Fig. 2. The sensor/telemetry part 215 has a bore 405. The bore 405 spans the entire length of the sensor/telemetry part 215 along the longitudinal axis 230. The mill part 210 has a bore 410. The bore 410 spans the entire length of the mill part 210 along the longitudinal axis 230. Efficient removal of milling debris from the rat hole 165 and the borehole 130 is improved when drilling mud flows quickly through the sensor/telemetry part 215 and the mill part 210. To facilitate this, the bore 405 and/or the bore 410 are enlarged and devices (e.g., sensors 220 and telemetry device 225) in the sensor/telemetry part 215 and in the mill part 210 are mounted such that they do not unduly reduce the size of the bore 405 and/or the bore 410. An obstruction does not unduly reduce the size of the bore 405 and/or the bore 410 if the obstruction reduces the size of the bore 405

and/or the bore 410 by less than 5 percent. An obstruction does not unduly reduce the size of the bore 405 and/or 410 if the obstruction reduces the size of the bore 405 and/or the bore 410 by less than 10 percent. An obstruction does not unduly reduce the size of the bores 405 and/or 410 if the obstruction reduces the size of the bore 405 and/or the bore 410 by less than 15 percent.

5 [0019] The bore 405 and/or the bore 410 have inside diameters 415 and 420, respectively, that are between 30 percent and 46 percent of their respective outside diameters 425 (measured at the stabilizer 235) of sensor/telemetry part 215 and 430 (measured at the mill 230) of mill part 210. This range insures that clean out is possible while maintaining the structural integrity of the milling tool 145 during milling operations. The range could be expanded above 46 percent to 60 percent
10 if the mill part 210 and the sensor/telemetry part 215 are manufactured from a high performance alloy, such as INCONEL® (a registered trademark owned by Huntington Alloys Corporation), capable of withstanding higher loads than conventional materials. A milling tool 145 in which the sensor/telemetry part 215 has an outside diameter 425 of 8.25 inches and an inside diameter 415 between 2.475 inches and 3.795 inches (in particular, an inside diameter of 3 inches) would fit into
15 this range. A milling tool 145 in which the mill part 210 has an outside diameter 430 of 8.25 inches and an inside diameter 420 between 2.475 inches and 3.795 inches (in particular, an inside diameter of 3 inches) would fit into this range.

[0020] The inside diameter 415 is not the same as the inside diameter 420. Conventional watermelon mills typically have outside diameters of 7 inches, 8.5 inches, and 9.5 inches, and
20 inside diameters ranging from 3 inches to 6 inches. In joining the sensor/telemetry part 215 to the mill part 210 it may not be possible or convenient to match the inside diameters, i.e. 415 and 420) of the two parts. For example, this may happen when mill part 210 is one of the larger watermelon mills.

[0021] Fig. 5 is a cross-sectional view of the watermelon mills with sensors and telemetry devices
25 of Fig. 3. The sensor/telemetry part 215 and the mill part 210 are integrated and the resulting tool has a bore 505 with an inside diameter 510 that is between 30 percent and 46 percent (and up to 60 percent if high performance alloys are used) of an outside diameter 515 of sensor telemetry part 215 along the longitudinal axis 230.

[0022] The sensor/telemetry part 215 includes a Workstring Orientation Tool (WOT), which is a workstring MWD system used for measurement of whipstock, deflector, and junction orientations in multilateral well systems.

[0023] Further, as indicated by the description of the WOT at <http://www.iwcdownhole.com/products/workstring-orientation-tool-wot/>, the WOT provides real-time survey data using mud pulse telemetry with thru-bore string access and adopts Intelligent Well Control's wall-mounted telemetry system. The outside diameter of the WOT measured at the WOT's stabilizer is 8.25 inches and the inside diameter is 3.00 inches.

[0024] Fig. 6 is a flow chart of a process for performing a milling operation using the watermelon mills with sensors and telemetry devices of Figs. 2 and 3. A milling tool, e.g., milling tool 145, is coupled to a lead milling tool, e.g., lead milling tool 150 (block 605). The milling tool 145 includes a sensor/telemetry part, such as sensor/telemetry part 215 and a mill part 210, as shown in Figs. 2-5. The sensor/telemetry part 215 includes a sensor, such as sensor 220, and a telemetry device, such as telemetry device 225. The mill part 210 includes a watermelon mill. The milling tool is coupled to a tubular, e.g., such as drill string 120 (block 610). A milling operation is performed by milling a multilateral window, such as window 160, in a borehole, such as borehole 130, using the lead milling tool and the milling tool attached to the tubular (block 615). During the milling operation, a parameter, such as weight on the milling tool, torque on the milling tool, bending stress on the milling tool, vibration on the milling tool, annulus pressure, bore pressure, flow rate of drilling fluids through the milling tool, and revolutions per minute of the milling tool, is measured using the sensor, e.g., sensor/telemetry part 215 (block 620).

[0025] Data retrieved from the milling tool 145 may be analyzed and stored in a database to improve current milling operations or future milling operations on existing wells, offset wells or future wells.

[0026] In one aspect, an apparatus includes a sensor/telemetry part, a telemetry device mounted on the sensor/telemetry part, a sensor mounted on the sensor/telemetry part, a mill part coupled to the sensor/telemetry part, a longitudinal axis through the sensor/telemetry part and the mill part, and a bore through the sensor/telemetry part and the mill part.

[0027] Implementations may include one or more of the following. The mill part may be integral with the sensor/telemetry part. The mill part may not be integral with the sensor/telemetry part. The mill part may include a watermelon mill. The sensor may include a work orientation tool. The sensor may be selected from the group consisting of a weight on bit sensor, a torque sensor, a bend sensor, a vibration sensor, a pressure sensor, a flow sensor, and a revolutions per minute (RPM) sensor. The bore may have an inside diameter of at least 3 inches. The bore may have an inside diameter of between 30 and 46 percent of an outside diameter of the sensor/telemetry part.

[0028] In one aspect, a method includes coupling a milling tool to a lead milling tool. The milling tool includes a sensor/telemetry part. The sensor/telemetry part includes a telemetry device and a sensor. The milling tool includes a mill part. The milling tool includes a longitudinal axis through the sensor/telemetry part and the mill part. The milling tool includes a bore through the milling tool along the longitudinal axis. The method includes coupling the milling tool to a tubular, performing a milling operation by milling a multilateral window in a borehole using the lead milling tool and the milling tool attached to the tubular, and measuring during the milling operation a parameter selected from the group consisting of weight on the milling tool, torque on the milling tool, bending stress on the milling tool, vibration of the milling tool, annulus pressure, bore pressure, flow rate of drilling fluids through the milling tool, and revolutions per minute (RPM) of the milling tool, using the sensor.

[0029] Implementations may include one or more of the following. The mill part may be integral with the sensor/telemetry part. The mill part may not be integral with the sensor/telemetry part. The sensor may include a work orientation tool (WOT). The sensor may be selected from the group consisting of a weight on bit sensor, a torque sensor, a bend sensor, a vibration sensor, a pressure sensor, a flow sensor, and a revolutions per minute (RPM) sensor. The method may include transmitting data concerning the parameter to a surface equipment using the telemetry device and using the parameter to control the drilling of the multilateral window in the borehole. The bore may have an inside diameter of between 30 and 46 percent of an outside diameter of the sensor/telemetry part

[0030] In one aspect, a system includes a tubular, a sensor/telemetry part coupled to the tubular, a telemetry device mounted on the sensor/telemetry part, a sensor mounted on the sensor/telemetry

part, a mill part coupled to the sensor/telemetry part, a longitudinal axis through the sensor/telemetry part and the mill part, and a bore through the sensor/telemetry part and the mill part along the longitudinal axis.

[0031] Implementations may include one or more of the following. The mill part may be integral with the sensor/telemetry part. The mill part may not be integral with the sensor/telemetry part. The mill part may include a watermelon mill. The sensor may include a work orientation tool (WOT). The sensor may be selected from the group consisting of a weight on bit sensor, a torque sensor, a bend sensor, a vibration sensor, a pressure sensor, a flow sensor, and a revolution per minute (RPM) sensor. The bore may have an inside diameter of between 30 and 46 percent of an outside diameter of the sensor/telemetry part

[0032] References in the specification to “one or more embodiments”, “one embodiment”, “an embodiment”, “an example embodiment”, etc., indicate that the embodiment described may include a particular feature, structure, or characteristic, but every embodiment may not necessarily include the particular feature, structure, or characteristic. Moreover, such phrases are not necessarily referring to the same embodiment. Further, when a particular feature, structure, or characteristic is described in connection with an embodiment, it is submitted that it is within the knowledge of one skilled in the art to effect such feature, structure, or characteristic in connection with other embodiments whether or not explicitly described.

[0033] One or more figures show block diagrams of systems and apparatus for a drilling system, in accordance with one or more embodiments. One or more figures show flow diagrams illustrating milling operations, in accordance with one or more embodiments. The operations of the flow diagrams are described with references to the systems/apparatus shown in the block diagrams. However, it should be understood that the operations of the flow diagrams could be performed by embodiments of systems and apparatus other than those discussed with reference to the block diagrams, and embodiments discussed with reference to the systems/apparatus could perform operations different than those discussed with reference to the flow diagrams.

[0034] The word “coupled” herein means a direct connection or an indirect connection.

[0035] The text above describes one or more specific embodiments of a broader invention. The invention also is carried out in a variety of alternate embodiments and thus is not limited to those described here. The foregoing description of an embodiment of the invention has been presented for the purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise form disclosed. Many modifications and variations are possible in light of the above teaching. It is intended that the scope of the invention be limited not by this detailed description, but rather by the claims appended hereto.

Claims

What is claimed is:

1. An apparatus comprising:
 - a sensor/telemetry part;
 - 5 a telemetry device mounted on the sensor/telemetry part;
 - a sensor mounted on the sensor/telemetry part;
 - a mill part coupled to the sensor/telemetry part;
 - a longitudinal axis through the sensor/telemetry part and the mill part; and
 - a bore through the sensor/telemetry part and the mill part along the longitudinal axis.
- 10 2. The apparatus of claim 1 wherein the mill part is integral with the sensor/telemetry part.
3. The apparatus of claim 1 wherein the mill part is not integral with the sensor/telemetry part.
4. The apparatus of claim 1 wherein the mill part comprises a watermelon mill.
5. The apparatus of claim 1 wherein the sensor comprises a work orientation tool.
6. The apparatus of claim 1 wherein the sensor is selected from the group consisting of a weight
15 on bit sensor, a torque sensor, a bend sensor, a vibration sensor, a pressure sensor, a flow sensor,
and a revolutions per minute (RPM) sensor.
7. The apparatus of claim 1 wherein the bore has an inside diameter of at least 3 inches.
8. The apparatus of claim 1 wherein the bore has an inside diameter of between 30 and 46 percent
of an outside diameter of the sensor/telemetry part.

9. A method comprising:

coupling a milling tool to a lead milling tool, the milling tool comprising:

a sensor/telemetry part comprising:

a telemetry device, and

5 a sensor,

a mill part,

a longitudinal axis through the sensor/telemetry part and the mill part, and

a bore through the milling tool along the longitudinal axis;

coupling the milling tool to a tubular,

10 performing a milling operation by milling a multilateral window in a borehole using the lead milling tool and the milling tool attached to the tubular; and

measuring during the milling operation a parameter selected from the group consisting of weight on the milling tool, torque on the milling tool, bending stress on the milling tool, vibration of the milling tool, annulus pressure, bore pressure, flow rate of
15 drilling fluids through the milling tool, and revolutions per minute (RPM) of the milling tool, using the sensor.

10. The method of claim 9 wherein the mill part is integral with the sensor/telemetry part.

11. The method of claim 9 wherein the mill part is not integral with the sensor/telemetry part.

12. The method of claim 9 wherein the sensor comprises a work orientation tool (WOT).

20 13. The method of claim 9 wherein the sensor is selected from the group consisting of a weight on bit sensor, a torque sensor, a bend sensor, a vibration sensor, a pressure sensor, a flow sensor, and a revolutions per minute (RPM) sensor.

14. The method of claim 9 further comprising:

transmitting data concerning the parameter to a surface equipment using the telemetry
25 device; and

using the parameter to control the drilling of the multilateral window in the borehole.

15. The method of claim 9 wherein the bore has an inside diameter of at least 3 inches.

16. The method of claim 9 wherein the bore has an inside diameter of between 30 and 46 percent of an outside diameter of the sensor/telemetry part.

17. A system comprising:

a tubular;

5 a sensor/telemetry part coupled to the tubular;

a telemetry device mounted on the sensor/telemetry part;

a sensor mounted on the sensor/telemetry part;

a mill part coupled to the sensor/telemetry part;

a longitudinal axis through the sensor/telemetry part and the mill part, and

10 a bore through the sensor/telemetry part and the mill part along the longitudinal axis.

18. The system of claim 17 wherein the mill part is integral with the sensor/telemetry part.

19. The system of claim 17 wherein the mill part is not integral with the sensor/telemetry part.

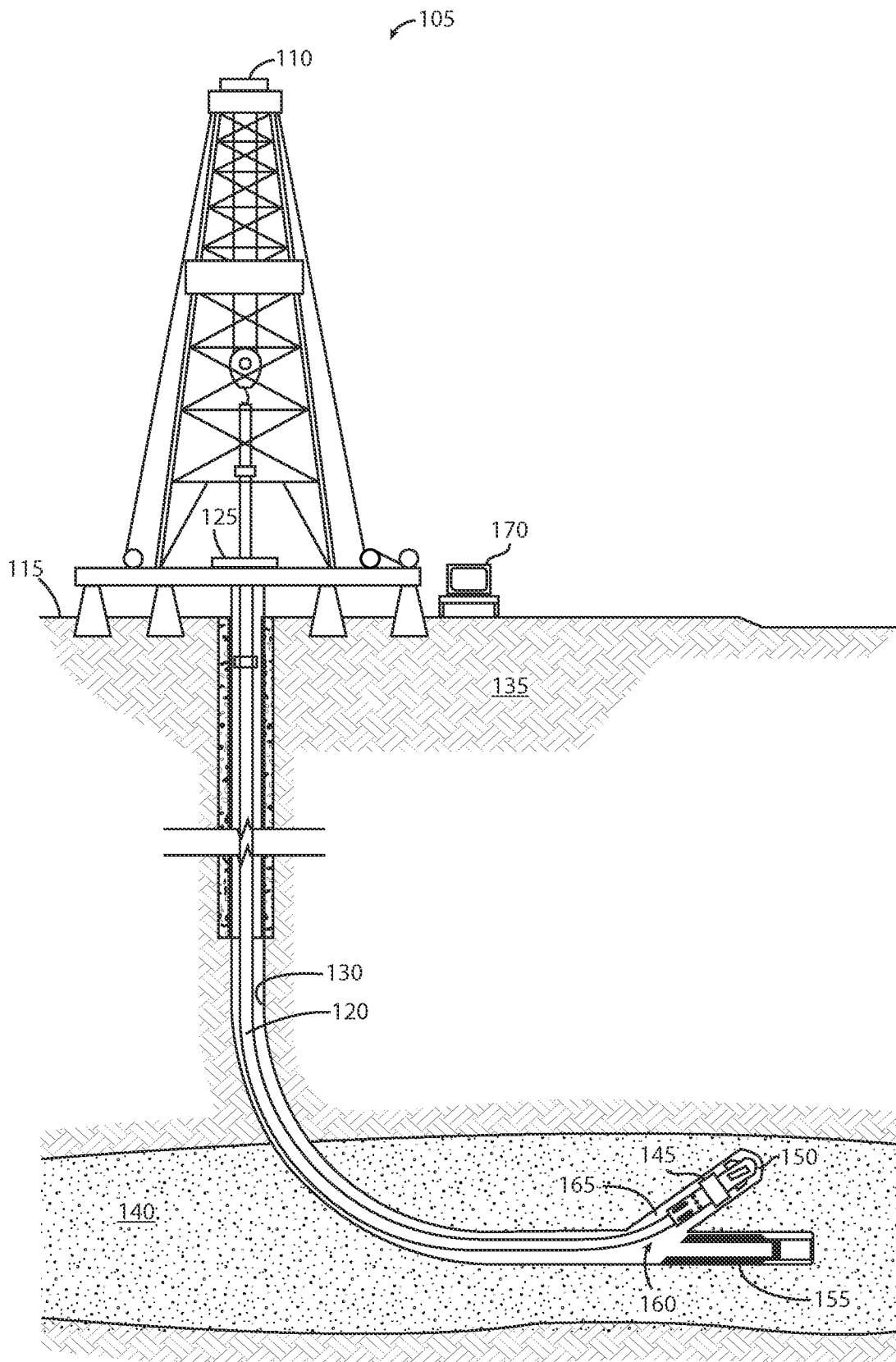
20. The system of claim 17 wherein the mill part comprises a watermelon mill.

21. The system of claim 17 wherein the sensor comprises a work orientation tool (WOT).

15 22. The system of claim 17 wherein the sensor is selected from the group consisting of a weight on bit sensor, a torque sensor, a bend sensor, a vibration sensor, a pressure sensor, a flow sensor, and a revolution per minute (RPM) sensor.

23. The method of claim 17 wherein the bore has an inside diameter of between 30 and 46 percent of an outside diameter of the sensor/telemetry part.

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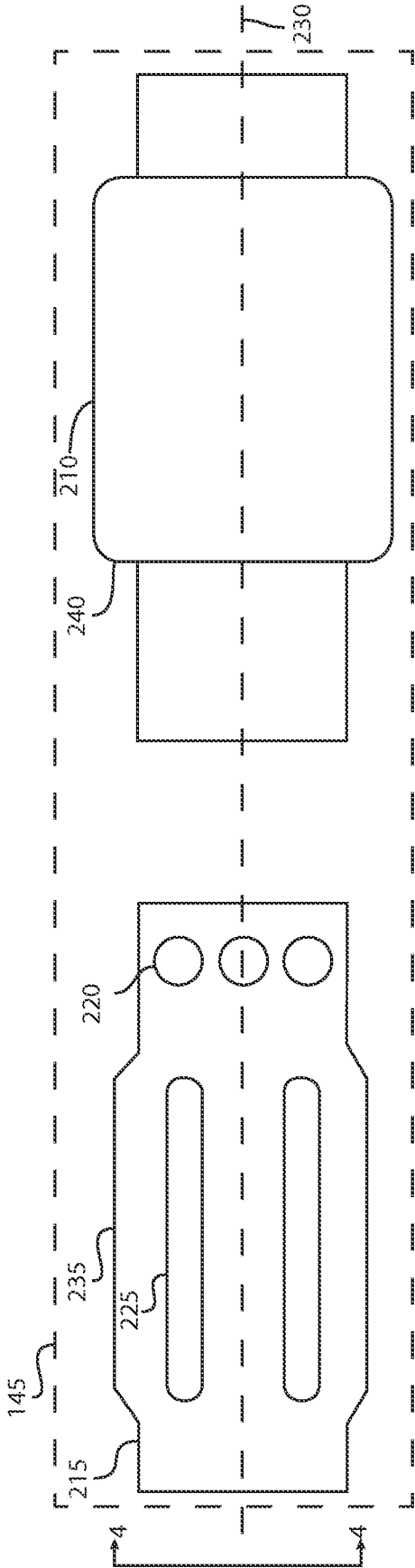


Fig. 2

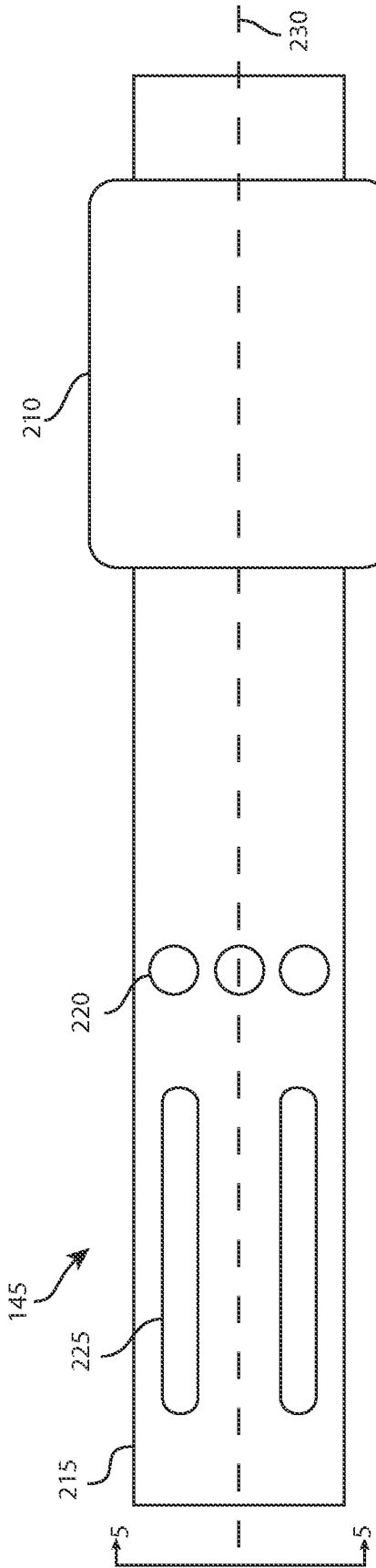


Fig. 3

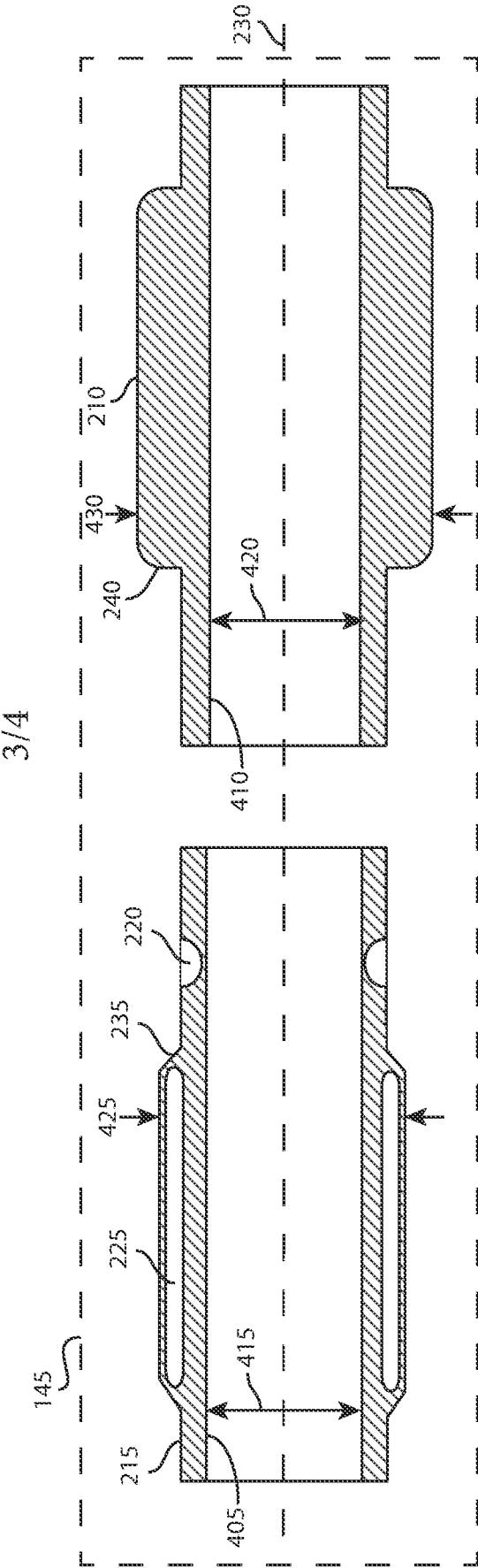


Fig. 4

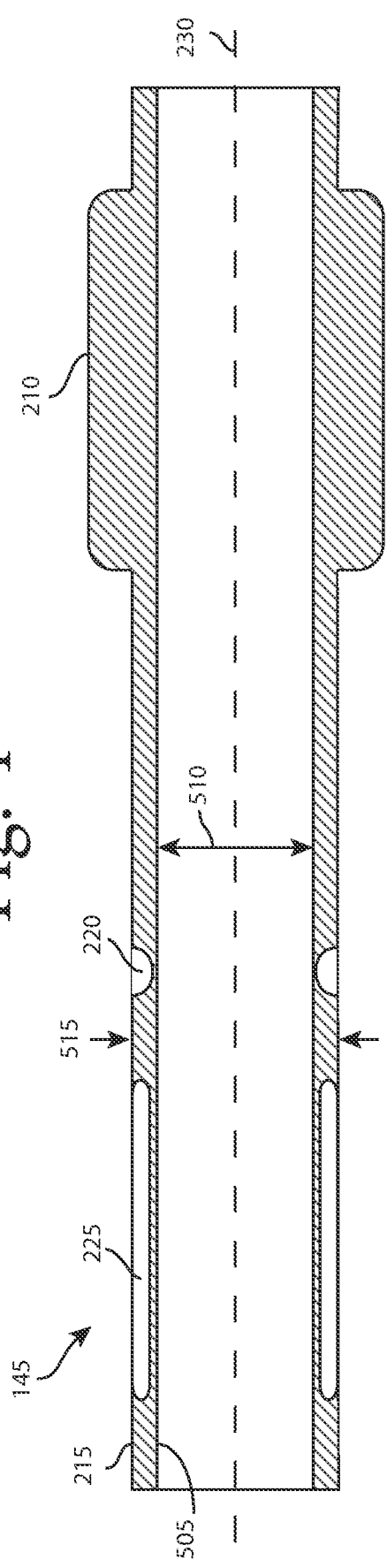


Fig. 5

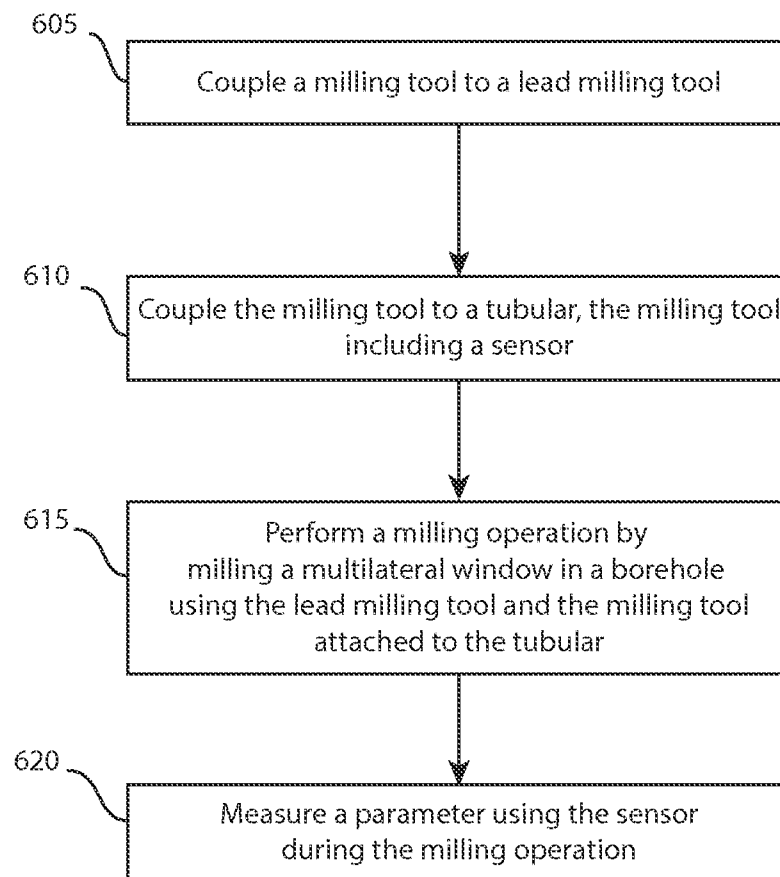


Fig. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/034978**A. CLASSIFICATION OF SUBJECT MATTER****E21B 47/12(2006.01)i, E21B 47/01(2006.01)i, E21B 47/06(2006.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

E21B 47/12; E21B 49/00; E21B 10/32; E21B 47/08; E21B 10/30; E21B 7/08; E21B 31/06; E21B 47/01; E21B 47/06

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: milling tool, sensor, telemetry, bore

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2012-0037422 A1 (RASHEED, WAJID) 16 February 2012 See paragraphs [0019], [0032], [0052]-[0064]; and figures 1-2.	1-23
A	US 2010-0282511 A1 (MARANUK et al.) 11 November 2010 See paragraphs [0015], [0085]; and figure 20.	1-23
A	WO 2012-116204 A2 (SMITH INTERNATIONAL, INC. et al.) 30 August 2012 See paragraphs [0024], [0031]-[0032]; and figure 1.	1-23
A	US 6474415 B1 (OHMER, HERVE) 05 November 2002 See column 4, line 53 - column 5, line 5; column 8, lines 51-65; and figures 2A, 6.	1-23
A	S 2012-0273187 A1 (HALL et al.) 01 November 2012 See paragraphs [0004]-[0006], [0025]-[0026]; and figures 3a-3b.	1-23

☐ Further documents are listed in the continuation of Box C.☒ See patent family annex.

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Date of the actual completion of the international search

06 November 2015 (06.11.2015)

Date of mailing of the international search report

09 November 2015 (09.11.2015)

Name and mailing address of the ISA/KR

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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